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Guidelines for Molded Interconnection Devices



A standard developed by the Institute for Interconnecting and Packaging Electronic Circuits



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Guidelines for Molded Interconnection Devices

ANSI/IPC-MB-380

A Standard developed by
the Molded Interconnection Device Subcommittee
of the Rigid Printed Board Committee
of the Institute for Interconnecting
and Packaging Electronic Circuits



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Lincolnwood, IL 60646 (708) 677-2850



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Acknowledgment

Any document involving a new technology combines material from a number of different sources. IPC-MB-380 is no exception. While the principle members of the Molded Interconnection Device Subcommittee are listed below, it is not possible to include all those who contribute to this document. To everyone who helped develop MB-380, the IPC and all users of this document extend their gratitude.

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D'Angelo, Richard A.	General Electric Co.	Nargi, Kathleen A.	Enthone Inc.
Davis, Thomas F.	AMP/Akzo JV, Inc.	Oakdale, Ray	Methode Electronics Inc./East
Dinella, Donald	AT&T Microelectronics	Osborne, Dr. Allan G.	Honeywell Inc.
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Fjelstad, Joe	Consultant	Robinson, John N.	Shipley Co.
Force, John	Delco Electronics	Schoenberg, Leonard	AT&T Bell Laboratories
Furness, Julian B.	Grimthorpe Enterprises	Sekutowski, Jan C.	AT&T Bell Laboratories
Galgoci, Ernest C.	Shell Development Co.	Sharma, Jag	Northern Telecom Canada Ltd.
Garrou, Phil	Dow Chemical	Simmons Jr., Archie E.	E.I. DuPont De Nemours & Co.
Gebert, Hansjürgen	Huls Troisdorf AG	Smith, George A.	Trace Laboratories - East
Genreau, David C.	DMG Engineering Associates	Sober, Douglas J.	Fortin Industries Inc.
Gilleo, Kenneth B.	Sheldahl Inc.	Spatola, Kenneth B.	Shipley Co.
Ginsberg, Gerald	Component Data Associates	Strohmer, John T.	Dept. of Defense
Goldman, Patricia	Enthone Inc.	Svensson, Jorgen	Ericson Telecom
Hafften, Kenneth E.	Bureau of Engraving Inc.	Templin, Jim	Allen-Bradley Co.
Haller, Richard	Pathtek	Theroux, Gil	Honeywell Inc.
Hamby, Bill	Hamby Corporation	Tibbetts, Ernest L.	Martin-Marietta Corp.
Hayes, Elmer P.	Dynachem Division	Tjelle, Phillip A.	Boeing Electronics Co.
Huie, Jack Y.	Unisys Corp.	Ulmer, Anthony	Dow Chemical
Jacobi, William I.	William Jacobi & Associates	Varnell, Daniel	Hercules Inc.
Kalmus Jr., Hank J.	Kalmus & Associates Inc.	Vellie, Larry	Vellie Circuits Inc.
Kalmus, Dr. Chris E.	C.E. Kalmus Corp.	Vollmar, Eric	Methode Electronics Inc.
Kenealey, Gerald W.	Control Data Corp.	Vosburg, Vivian	Teradyne Telecommunication
Kingston, Terry	Methode Electronics Inc.	Webster, Stephen P.	PPG Industries Inc.
Kinney, L. Philip	Allen-Bradley Co.	Wood, Tom A.	Amoco Performance Prod Inc.
Kirschenbaum, Jerry	Trace Laboratories—West	Wynschenk, Jo	Enthone Inc.

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Guidelines for Molded Interconnection Devices

1.0 Introduction Molded Interconnection devices (hereafter referred to as "molded interconnects") combine a molded plastic substrate with a circuitry pattern to provide both the mechanical and the electrical functions of an electronic interconnection package. Molding provides unique 3-dimensional interconnection benefits that conventional printed boards cannot match. The ability to create 3-dimensional features and meet unusual design requirements is the most exciting aspect of this new and increasingly complex technology. The driving force behind the technology, though, has been the demand for a better and less expensive electronic package design. Molded interconnects meet this demand.

Molded interconnect technology has grown tremendously over the past few years. Products are now in volume production in each of the three subgroups defined below, and the number of such products increases constantly.

1.1 Scope This document was created to increase general understanding of molded interconnect technology. Information on candidate materials, molding processes, fabrication processes and test methods is included for suppliers, designers, and end-users. This document is not intended to be a complete Designer's Guide to Molded Interconnects. If you are considering using molded interconnects you should discuss your needs with the appropriate suppliers and designers.

1.2 Purpose Molded interconnects can be divided into three major subgroups:

Subgroup 1—Interconnects having two dimensional features with conductive patterns in two dimensions.

Subgroup 2—Interconnects having three dimensional features with conductive patterns in two dimensions.

Subgroup 3—Interconnects having three dimensional features with conductive patterns in three dimensions.

Each subgroup requires different levels of design and fabrication expertise.

Subgroup 1 can be compared with existing planar circuit board applications, although the design and fabrication techniques may be completely different, some properties may improve, and the cost may be lower.

Subgroup 2 begins to incorporate the real benefits of molding through 3-dimensional features as the interconnection part encompasses both mechanical and electrical functions.

Subgroup 3 takes full advantage of the benefits available through molding and includes applications not possible with conventional planar printed circuit boards. Molded interconnects evolved to meet new demands in the electronics industry. The

following are some of the potential advantages of this new technology:

- Lower system cost through part integration and elimination of manufacturing steps.
- Low dielectric constants and low dielectric loss properties of thermoplastic materials compared to conventional base materials.
- High resistivity to electrical leakage and good electrical properties.
- Low coefficients of thermal expansion (CTE) in the Z-axis and improved thermal performance.
- Some base materials are inherently flame resistant and meet UL-94VO requirements.
- Suitable for hostile environments.
- Suitable for elevated temperature use.
- Improved mechanical tolerances.
- Improved consistency/reliability through molding.
- Reduced Fiberglass exposure reduces assembly problems and related health concerns.
- Ability to mold-in functional 3-dimensional features.
- Ability to mold-in recessed pads for reliable placement of surface mounted components.

Of course, there can be potential disadvantages to molded interconnects, such as the following:

- Up-front tooling costs and long lead times for molds.
- Costs to change electrical and/or mechanical design.
- Limited source of supply of fabricated parts due to newness and diversity of technology.
- Significant volumes may be required to make it cost competitive.
- Fine line widths and spacings may not be possible or economically feasible for some fabrication processes.
- Modified process controls may be required during the soldering operation due to thermal limitations of some base materials.
- Limited multilayer capability
- Adhesion values and/or test methods on molded interconnects may not be comparable to conventional printed circuit boards.
- Limitations of conductive pattern and/or component placement on or near 3-dimensional features may exist.
- Overall product size is limited.

Close working relationships between customers and suppliers are necessary to take *full* advantage of the benefits offered by this new technology and to appreciate its limitations. In addition, early involvement of both electrical and mechanical designers is

advantageous in order to realize the full potential of this technology.

Various methods of molded interconnect design and fabrication currently available are outlined in this document. Since each method varies in its capabilities and limitations, a close review of each will help you determine if the technology of molded interconnects is a viable and valuable alternative for your needs. Whichever method you choose for your electronic packaging needs, molded interconnect technology may allow a product design never feasible before.

1.3 Application and Classification Molded interconnects applications can exist for market categories defined below. Applications may be of any of the three subgroup types.

- 1) Automotive
- 2) Business, Retail, Education
- 3) Communications
- 4) Consumer Electronics
- 5) Computer & Peripheral
- 6) Government & Military
- 7) Industrial Electronics
- 8) Instrumentation

Examples of some applications in these market categories can be found in Section 6.

2.0 Documentation

2.1 Applicable Documents The following documents, of the issue currently in effect, form a part of this document to the extent specified herein.

2.1.1 Institute For Interconnecting And Packaging Electronic Circuits (IPC)¹

IPC-T-50 Terms and Definitions

IPC-TM-650 Test Methods Manual

For convenience, all IPC-TM-650 test methods referenced herein are reprinted at the end of this standard. Refer to IPC-TM-650 for the latest test method revision.

- 2.1.1 Microsectioning
- 2.3.25 Resistivity of Solvent Extract
- 2.3.26 Ionizable Detection of Surface Contamination (Dynamic)
 - 2.3.26.1 Ionizable Detection of Surface Contamination (Static)
- 2.3.38 Surface Organic Contaminant Detection Test
- 2.3.39 Surface Organic Contaminant Identification Test
- 2.4.1 Adhesion, Plating
- 2.4.18 Tensile Strength and Elongation, Copper Foil
- 2.4.8 Peel Strength, Metal Foil
- 2.4.22 Bow & Twist

- 2.5.5.3 Permittivity (Dielectric Constant) and Loss Tangent (Dissipation Factor) of Materials (Two Fluid Cell Method)
- 2.5.5.5 Stripline Test for Permittivity and Loss Tangent (Dielectric Constant and Dissipation Factor) at X-Band
- 2.5.6 Dielectric Strength, Rigid Printed Wiring
- 2.5.7 Dielectric Withstanding Voltage, Printed Wiring Material
- 2.5.17.1 Volume Resistivity and Surface Resistivity of Printed Wiring Laminate
- 2.6.3 Moisture and Insulation Resistance, Rigid, Rigid/Flex and Flex Printed Wiring Boards
- 2.6.4 Outgassing, Multilayer Printed Wiring
- 2.6.7 Thermal Shock and Continuity, Flexible Printed Wiring

IPC-S-804 Solderability Test Method for Printed Boards

IPC-CC-830 Qualification and Performance of Electrical Insulating Compounds for Printed Wiring Boards

IPC-SM-840 Qualification and Performance of Permanent Polymer Coating (Solder Mask) for Printed Boards

2.1.2 American Society For Testing And Materials

ASTM D149 Electrical Insulation Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies

ASTM D150 AC Loss Characteristics and Permittivity

ASTM D256 Impact Resistance of Plastics

ASTM D257 DC Resistance or Conductance of Insulating Materials

ASTM D495 High Voltage, Low Current, Dry Arc Resistance of Solid

ASTM D570 Water Absorption of Plastics

ASTM D638 Tensile Properties of Plastics

ASTM D648 Deflection Temperature of Plastics Under Flexural Load

ASTM D790 Flexural Properties of Plastics

ASTM D1238 Flow Rates of Thermoplastics by Extrusion Plastometer

ASTM D1525 Vicat Softening Temperature of Plastics

ASTM D1897 Injection Molding Test Specimens of Thermoplastic Injection Molding and Extrusion Materials

2.1.3 Underwriters Laboratory

UL 94 Tests for Flammability of Plastic Materials

UL 746B Standard for Polymeric Materials—Long Term Property Evaluations

UL 796 Printed Wiring Boards

2.2 Reference Documents Documents listed here are for reference purposes to assist the user.

2.2.1 Institute For Interconnecting And Packaging Electronic Circuit (IPC)

IPC-D-319 Design Performance Standard for Rigid Single- and Double-Sided Printed Boards

IPC-SD-320 Standard for Rigid Single- and Double-Sided Printed Boards

IPC-SM-782 Surface Mount Land Patterns (Configurations and Design Rules)

IPC-AJ-820 Assembly and Joining Handbook

3.0 Terms And Definitions Terms and definitions used herein are in accordance with IPC-T-50 except as otherwise specified. **Note:** Any definition denoted with an asterisk (*) is a reprint of the definition defined in IPC-T-50.

Additive Process* A process for obtaining conductive patterns by the selective deposition of conductive material on clad or unclad base material (see also "Semi-Additive Process" and "Fully Additive Process").

Amorphous Polymer A polymer with a random, unstructured molecular configuration.

Catalyze To accelerate a chemical change or reaction by the addition of a substance that is not permanently affected by the reaction.

Copolymerize To create a polymer by joining two or more different monomers in a repeating chain.

Crystalline Polymer A polymer with a regular, structured molecular configuration.

Dielectric Strength* The maximum voltage that a dielectric can withstand at a given thickness under specified conditions without resulting in a voltage breakdown, usually expressed as volts/unit dimension (See ASTM D149 test method).

Dissipation Factor A ratio of the energy dissipated (lost) as heat compared to that transmitted, usually measured at 1 MHz (10^6 cycles/sec) (See ASTM D150 test method).

Elongation The increase in gage length (measured after rupture) divided by original gage length. It is a measure of the ductility of the material determined in a tensile test (See ASTM D638 test method).

Filler A substance used in manufacturing plastics to provide solidity, bulk, or other properties.

Flexural Modulus A ratio of maximum fiber stress to maximum strain within elastic limit of stress-strain diagram obtained in flexural test (See ASTM D790 test method).

Flexural Strength The strength of a material in bending expressed as the tensile stress of the outermost fibres of a bent test sample at the instant of failure (See ASTM D790 test method).

Fully Additive Process* An additive process wherein the entire thickness of electrically isolated conductors is built up by electroless metal deposition. (A non-preferred synonym is "Fully Electroless.")

Heat Deflection (Distortion) Temperature (HDT) Also referred to as Deflection Temperature Under Load (DTUL), the temperature at which a plastic specimen deforms a specified amount under a specified load. It is not a direct guide to the high temperature limit of a plastic for a specified application, but rather a means for comparing the relative heat resistance of plastics (See ASTM D648 test method).

Photopolymer A photo-sensitive plastic used in some imaging processes.

Plastic Any of a group of synthetic or natural organic materials that may be shaped when softened then hardened, including many types of resins, resinoids, polymers, cellulose derivatives, casein materials.

Polymerize To form a polymer or polymeric compound by joining together many smaller molecules which may all be of one type or a mixture of types.

Polymer A compound of high molecular weight derived either by the addition of many smaller molecules, which may be of one type or more than one type, or by the condensation of many smaller molecules with the elimination of water, alcohol, or some other solvent.

Runners The channels (or the solid material from these channels) that connects the sprue with the gate to the mold cavities in an injection or transfer mold.

Semi-Additive Process* An additive process for obtaining conductive patterns that combines an electroless metal deposition on an unclad or thin-foil base material with electroplating, etching, or both.

Specific Gravity The ratio of the density of any substance to the density of some other substance, often water, taken as a standard.

Sprues The feed opening (or the solid material formed at this opening) through which molten plastic enters a mold in an injection or transfer mold.

Thermoplastics A plastic which can be repeatedly softened and reshaped by heat and then hardened by cooling, without any significant change in the inherent properties.

Thermosets Any plastic that undergoes a chemical reaction leading to a relatively infusible or crosslinked state which cannot be softened or reshaped by subsequent heating.

Tensile Modulus Also referred to as modulus of elasticity, is essentially a measure of stiffness. It is the ratio of the applied stress to the strain it produces in the region in which strain is linearly proportional to stress (See ASTM D638 test method).

Tensile Strength The resistance of a material to longitudinal stress, measured by the minimum amount of longitudinal stress required to rupture the material, usually expressed in [psi] (see ASTM D638 test method).

U.L. Relative Thermal Index An extrapolated temperature at which a 50% reduction in properties is expected for a given material thickness at an arbitrary period (usually about 11,000 hr.) of exposure to the temperature (See UL 746B test method).

Volume Resistivity The ratio of the potential gradient parallel to the current in the material to the current density, measured in ohms times the area of the smaller electrode divided by the thickness of the specimen (See ASTM D257 test method).

4.0 Materials of Construction

4.1 Plastics

4.1.1 Thermoplastics As of January 1990, the following thermoplastic materials are being used or evaluated as substrates for 3D and planar molded interconnects:

Table 4-1 Thermoplastic Substrate Materials¹

Name	Abbreviation
Crystalline Polyamide	– CPA*
Liquid Crystal Polymer	– LCP*
Polyarylate	– PAR°
Polyarylsulfone	– PAS°
Polybutylene terephthalate	– PBT*
Polycyclohexane dimethanol terephthalate	– PCT*
Polyethylene terephthalate	– PET*
Polyetherimide	– PEI°
Polyethersulfone	– PES°
Polyphenylene Sulfide	– PPS*
Polysulfone	– PSO°

° Amorphous

* Crystalline

¹ As contributed by subcommittee participants

Plastics are categorized as either thermoplastic or thermoset. Thermoplastics can be repeatedly softened by heat and hardened by cooling.

Thermoplastics can be categorized as either amorphous or crystalline. The molecular configuration of amorphous polymers is random; therefore, their properties tend to be uniform in all directions relative to the flow. Unfilled amorphous polymers are usually transparent, exhibit very low warpage, and are somewhat more susceptible to chemical attack than crystalline polymers.

Crystalline polymers exhibit a regular, structured molecular configuration. They tend to warp more than amorphous polymers since properties like shrinkage rate depend on the molecular configuration in each direction relative to flow. Crystalline polymers are usually opaque and resist chemical attack more than amorphous polymers. Since thermoplastics vary widely in chemical resistance, you should consult the resin supplier for more specific information. Tremendous increases in thermal performance are achieved by the addition of glass and minerals to crystalline resins.

When considering substrate materials for molded interconnects, two important considerations are soldering needs and circuitization technology. Soldering temperatures may exceed the dimensional stability and thermal capabilities of the substrate material. The type of soldering desired, exposure time, and soldering temperature all combine to determine whether a particular material can or cannot be used. If an application does not require soldering, then low temperature/lower cost resins can be used. Some circuitization technologies can only be used on certain substrate materials. Table 4-2 (divided into four parts) lists many properties for the materials in Table 4-1. These numbers are only illustrative of typical resin family properties. Specific values for any engineering calculations should be obtained from the manufacturer's data sheets.

4.1.2 Thermosets Thermosets are materials that undergo a chemical reaction leading to a relatively infusible or crosslinked state. Since their reaction takes place in the mold, cycle times for thermosets usually exceed those of thermoplastics. Subsequent heating, though it may soften the material somewhat, cannot restore the flowability of the uncrosslinked, uncured resin. Phenolics, epoxies, crosslinked polyesters and urea-formaldehyde resins are typical thermosets.

4.2 Materials (Other than Plastic)

4.2.1 Introduction During the manufacture of molded interconnects, numerous other materials may be used in the manufacturing process. For example, the molded plastic part will have a conductive pattern applied. The methods for applying the conductive patterns are outlined in Section 5.

This section outlines several of those materials which are used in the manufacture of molded interconnects and which remain with the product delivered to the customer. This section will not attempt to outline materials used during the manufacturing process which do not remain on the shipped product.

The materials that are outlined in this section are not necessarily used in all manufacturing processes, and there may be materials used in manufacturing which are not discussed here due to proprietary reasons. For an exact understanding of the materials used in a specific manufacturing process, the reader should consult the molded interconnect fabricator.

4.2.2 Conductive Materials Different molded interconnect suppliers may use different conductive materials and application methods. Conductive materials are typically metals such as copper, nickel, gold, tin, palladium, and conductive polymers as are used in standard printed circuit boards. Each application method has unique properties and advantages. Each application will determine the preferable application methods and conductive materials. For example, certain application methods may not permit three dimensional conductive patterns; others may not permit plated through holes. Adhesion levels may differ between methods, and so on. Therefore, you should review your requirements with several suppliers to identify which system best suits your application.

Table 4-2, Part 1

	ASTM Method	CPA Filled	LCP	LCP Filled	PAR	PAR 30% GF
Mechanical						
Tensile strength MPa [10 ³ psi]	D638	172 [25]	165-207 [24-30]	97-241 [14-35]	69 [10]	145 [21]
Tensile modulus MPa [10 ³ psi]	D638	8273 [1,200]	9652-19303 [1,400-2,800]	10341-37917 [1,500-5,500]	2070 [300]	8273 [1,200]
Flexural strength MPa [10 ³ psi]	D790	216 [31.4]	169-241 [24.5-35.5]	159-317 [23-46]	75.8 [11]	207 [30]
Flexural modulus MPa [10 ³ psi]	D790	7652 [1,110]	8962-15169 [1,300-2,200]	10341-31712 [1,500-4,600]	2137 [310]	8411 [1,220]
Elongation @ Break %	D638	2.0	1.3-3.0	1.0-6.6	50	2
Thermal						
Deflection Temp. Under Load (DTUL) @ 264 PSI, °C [°F]	D648	247 [477]	180-200 [356-392]	180-346 [356-655]	174 [345]	171 [340]
U.L. relative thermal index °C	—	Testing in Process	—	200-260	130-140	—
Coefficient of Expansion PPM/°C	X Y Z	D696	46 — —	0-5 40-75 —	62-76 62-76 62-76	27 56
Electrical						
Dielectric 10 ⁶ H _z at 22.8°C [73°F]	D150	3.9	3.6	3.5-4.2	3.30	3.43
Dielectric strength volts/mm [volts/mil] at 3.18 mm [0.125 inch]	D149	570	38600 [980 ^B]	25200-43300 [640-1100]	15700 [400]	15900 [405]
Dissipation factor at 22.8°C [73°F]	60H _z 10 ³ H _z 10 ⁶ H _z	D150	— 0.018 0.028	0.004 ^E 0.034	0.004-0.006 ^E 0.020	— 0.018
Volume resistivity ohm-cm	D257	>10 ¹⁸	10 ¹⁶	>10 ¹⁵	>10 ¹⁶	10 ¹⁶
Other						
Specific gravity	D792	1.38	1.40	1.48-1.89	1.21	1.44
Flammability @ 1.59 mm [0.0625 inch]	UL94	VO	V-O	VO	VO	VO
Moisture absorption 24 hr., %	D570	0.2	0.02-0.03	0.02-0.04	0.27	

4.2.2.1 Liquid Platable Systems Conductive patterns may be applied to molded interconnects through a variety of methods. One method, similar to that used with epoxy fiberglass PCB's, is through liquid plating techniques. These plating techniques fall into three categories: fully additive (also known as fully electroless), semi-additive, and subtractive. These are defined as follows:

Fully-additive—An additive process wherein the entire thickness of electrically isolated conductors is built-up by electroless metal deposition.

Semi-additive—An additive process for obtaining conductive patterns which combines non-selective conductive deposit on an unclad substrate with electroplating, with etching or with both.

Electroless platable metals include copper, nickel, tin, palladium, and gold. Plating rates for electroless metals are typically 25-102 μ m [1-4 micro inches] per minute. Electroless metal deposits generally provide uniform metal deposits on complex parts without excessive build-up on projections or edges.

Electroplateable metals include copper, nickel, gold, tin-lead, tin and palladium. Electroplating baths typically deposit from

0.025-0.064 mm [1 to 2.5 mils] of metal per hour and provide good leveling qualities on planar surfaces.

The resistivity for plated copper by either the additive or semi-additive process is 1.7-1.9 microhm-cm.

4.2.2.2 Polymer Thick Films Polymer conductors can be used on molded interconnects. Generally, these polymeric conductors are applied to the molded interconnect directly through printing or are printed onto release paper and then transferred to the molded interconnect.

Polymeric conductive inks typically consist of three basic components: conductive powder, polymer, and solvent, although minor amount of other additives may be included as needed (e.g. wetting and printing aids, adhesives). Silver is the predominant metal used. Other lower cost powders, such as copper and nickel, may also be used. However, silver flake based formulas are preferred because they offer higher density coatings, longer conductor stability, and moderate cost. For 0.025 mm [0.001 inch] thickness, resistivity for silver-based conductors may range from 3000-100,000 microhm-cm.